INDOOR AIR QUALITY ASSESSMENT

Jacobs Elementary School
180 Harbor View Road
Hull, Massachusetts 02405

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of parents, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality concerns at the Jacobs Elementary School (JES) in Hull, Massachusetts. Specific concerns regarding asbestos, construction and mold growth prompted the assessment.

On September 20, 2006, a visit to conduct an assessment of the JES was made by Cory Holmes an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Mr. Holmes was accompanied by Kevin O'Brien, Director of the Hull Health Department during the assessment. Also accompanying Mr. Holmes for portions of the assessment were David Twombly, Director of Operations, Hull Public Schools (HPS) and Principal Raymond Joyal.

The JES is a two-story red brick building that was constructed in 1968. A modular wing consisting of four classrooms and an office were subsequently added. The modular classroom wing is connected to the main building by an unheated, uninsulated wooden passageway. The JES is currently in the beginning phases of a new construction/renovation project that began in July 2006. At the time of the assessment, preparations were being made to start construction of a new addition, which will be adjacent to the existing building. Once completed, the new addition will house students and staff while the existing building is renovated. The project is tentatively scheduled for completion in August of 2007. The cafeteria is sectioned into quarters and is being used to house four classrooms. Windows are openable in the building but reportedly difficult to operate in a number of areas.

The building was previously evaluated by Mr. Elise Comproni and Jeffery Purvis of the MDPH in October of 1996 and a report was issued indicating problems that were identified at that time (MDPH, 1997). The building was recently visited in September (2006) by OASIS Environmental Contracting Services, Inc. (OASIS), due to reports of mold growth. OASIS recommended the removal of carpeting, ceiling tiles, insulation and inspection and removal (if necessary) of all other porous items in effected classrooms located on the first floor of the main building. Abatement activities were recommended by OASIS to be done with containment and negative pressure/filtration, followed by a complete cleaning, disinfection and vacuuming of all flat surfaces using a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner (OASIS, 2006a).

Mr. Twombly reported that during carpet removal asbestos concerns were raised regarding floor tiles in classrooms undergoing abatement. As a result, American Environmental Consultants, Inc. (AEC) was retained by the HPS to perform a reinspection to visually inspect and assess all friable and non-friable known or assumed asbestos-containing building materials (ACBM) in compliance with the US Environmental Protection Agency's (USEPA) Asbestos Hazard Emergency Response Act (AHERA) (40 CFR Part 763.85(b)). Based on their findings, AEC recommended that loose/buckling floor tiles be removed (AEC, 2006). Tiles were removed and floors were sealed in these and several other classrooms in conjunction with the mold abatement. Additional tiles were removed and replaced with vinyl floor tiles in the first floor main hallway (Picture 2).

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity were conducted with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particulate matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using an HNu, Model 102 Snap-on Photo Ionization Detector (PID). CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

This JES houses approximately 500 pre-kindergarten through grade 5 students and approximately 55 staff. Tests were taken under normal operating conditions and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that the carbon dioxide levels were elevated above 800 parts per million (ppm) in ten of thirty-two areas surveyed, indicating inadequate air exchange in approximately one-third of the areas surveyed. Of note was the modular classroom wing where carbon dioxide levels ranged from 1,464 to 3,876 ppm. It is important to mention that several areas had opened windows or were sparsely populated at the time of the assessment, which can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to be higher with full occupancy and with windows closed. It is also important to note that the mechanical ventilation systems were deactivated throughout the building at the time of the assessment (with the exception of the modular classroom wing and gymnasium); therefore no means to mechanically introduce fresh, outside air was being provided to the majority of areas.

Ventilation for modular classrooms is provided by rooftop AHUs (Picture 3). Fresh air is distributed to classrooms via ductwork connected to ceiling-mounted air diffusers and drawn back to the AHUs through return grilles. Thermostats control each heating, ventilating and air conditioning (HVAC) system and have fan settings of "on" and "automatic". Thermostats were set to the "automatic" setting (Picture 4) during the assessment. The automatic setting on the thermostat activates the HVAC system at a preset temperature. Once the preset temperature is reached, the HVAC system is deactivated. Therefore, no mechanical ventilation is provided until the thermostat re-activates the system. In addition, the AHUs were operating in air conditioning mode during the assessment, which can limit outside air intake on hot, humid days. Limiting outside air intake can contribute to an increase in carbon dioxide levels. The mechanical ventilation in the modular classroom office was not operating during the assessment.

Fresh air in the majority of classrooms is supplied by unit ventilators (univents) (Picture 1). A univent is designed to draw air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 5). Return air is drawn through an air intake located at the base of each unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. Univents are original equipment to the building (approximately 40-50 years old). Efficient function of such aged equipment is difficult to maintain, since compatible replacement parts are often unavailable.

Exhaust ventilation is provided by vents located in the ceilings of coat closets (Picture 6), powered by rooftop motors. Air is drawn into the coat closet from the classroom via undercut closet doors (Picture 7). MDPH staff did not detect any draw of air from the exhaust vents at the time of the assessment, which can indicate that they were deactivated or inoperable. The location of the closet vents also allows them to be easily blocked by stored materials.

As previously mentioned, the cafeteria was reconfigured into four classrooms. Elevated carbon dioxide levels were measured in two of the four cafeteria classrooms (Table 1). Mechanical ventilation in the cafeteria provided by an AHU ducted to ceiling-mounted air diffusers (Picture 8). Exhaust ventilation is provided by wall-mounted exhaust vents. Although each of the four classrooms is equipped with supply ventilation, the division of the cafeteria has left two areas without exhaust ventilation. As with the univents, these systems were not operating during the assessment. The two classrooms below 800 ppm were located on the exterior wall and had windows open during the assessment. Without adequate supply and exhaust ventilation, excess heat and environmental pollutants can build up and lead to indoor air/comfort complaints. At the conclusion of the assessment CEH staff recommended to Principal Joyal and Mr. Twombly, that *all* mechanical ventilation systems be reactivated and that windows be used to supplement mechanical ventilation throughout the building (and in particular, the modular classroom wing) to introduce fresh outside air.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (BOCA, 1993; SBBRS, 1997). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches (Appendix A).

Temperature readings during the assessment ranged from 68^{o} F to 80^{o} F, which were within the MDPH comfort guidelines in most areas. The MDPH recommends that indoor air temperatures be maintained in a range between 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., supply/exhaust ventilation not operating).

Relative humidity measurements ranged from 40 to 63 percent, most of which were within or close to the upper range of the MDPH recommended comfort range in the areas surveyed. The MDPH recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. While temperature is mainly a comfort issue, relative humidity in excess of 70 percent for extended periods of time can provide an environment for mold and fungal growth (ASHRAE, 1989). During periods of high relative humidity (late spring/summer months), windows and exterior doors should be closed to keep moisture out. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Odors/Microbial/Moisture Concerns

At the time of the assessment the building had undergone extensive mold remediation by OASIS. Occupants however, reported on-going concerns regarding leaks and odors in the modular classroom wing. Active leaks were reported from roof drains located inside the corridor of the modular classroom wing (Pictures 9 and 10). This was evidenced by standing water observed on top of student lockers below the drains, most likely resulting from rains that occurred in the Hull area the evening prior to the CEH assessment (Weather Underground, 2006). A small area that appeared to be mold growth was observed on the surface of a plastic drain pipe near the lockers (Picture 11). It was reported by Mr. Twombly that on-going attempts are being made to repair the drains. CEH staff recommended to Mr. Joyal in subsequent correspondence that the lockers be relocated until the leaks are repaired.

CEH staff identified the following sources/conditions contributing to odors in the modular classroom wing and in particular the modular classroom office (MCO):

- A box containing a large number of mold-colonized books (Pictures 12 and 13);
- a strong odor of urine and other associated restroom odors in the boy's restroom that had no operating local exhaust ventilation (Picture 14);
- weakly operating local exhaust ventilation in the adult restroom, which would not be sufficient to remove odors;
- water damaged ceiling tiles in restrooms (Picture 14); and
- a water cooler on water-stained carpeting.

These point sources for odors coupled with the lack of air exchange in the modular classroom wing are likely responsible for odors in this area.

A few areas on both the first and second floor also had water-damaged ceiling tiles (Picture 15), which can indicate current or historic leaks from the roof or plumbing system. Water-damaged ceiling tiles can provide a source for mold growth and should be replaced after a water leak is discovered and repaired.

The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

JES staff reported water infiltration in the modular classroom passageway, most likely from poor drainage. This condition has resulted in past water damage and mold growth on wooden passageway walls. In addition, JES staff reported that in the winter water freezes and creates a physical hazard inside the passageway. At the time of the assessment this area had been cleaned, disinfected and sealed by OASIS. CEH staff observed missing elbow extensions at the base of downspouts around the modular classroom wing (Picture 16). Gutters and downspouts are designed to collect and drain water *away* from the building.

Renovations and Other IAQ Evaluations

It is important to note that the State Department of Education amended their regulations in 1999 to address concerns associated with school renovation projects in Massachusetts (MDOE, 1999). These regulations were subsequently adopted by the Massachusetts School Building Authority (MSBA) in September 2006, to prevent exposure of building occupants to construction/renovation pollutants. These regulations require that schools receiving funds under the program for construction or renovation projects must confer with the most current edition of the "IAQ Guidelines for Occupied Buildings Under Construction" published by the Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA) 963 CMR 2.04(2)(c),(d).

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, CEH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On the day of assessment, outdoor carbon monoxide concentrations were non-detect (ND) (Table 1). Carbon monoxide levels measured in the school were also ND (Table 1).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2006). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 35 $\mu g/m^3$ over a 24-hour average (US EPA, 2006). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 12 $\mu g/m^3$ (Table 1). PM2.5 levels measured in occupied areas of the school ranged from 5 to 40 $\mu g/m^3$, which were mostly below the NAAQS of 35 $\mu g/m^3$ (Table 1). Classroom 14 was equal to and the special education room was slightly above the NAAQS of 35 $\mu g/m^3$ (Table 1). Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulate may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors.

Concerns were raised about outdoor construction activities and their potential impact on indoor air quality. CEH staff observed a number of construction vehicles and several large piles of dirt/construction debris around the perimeter of the building (Pictures 17 and 18). This activity should be closely monitored to prevent the entrainment of vehicle exhaust and other fugitive dust/debris from construction from entering the building via univents, open doors or windows. A number of classrooms adjacent to the construction zone had open windows during the assessment (Picture 17). The opening of windows allows for unfiltered air to enter the classroom environment carrying with it airborne dirt, dust and particulates. Thus, opening windows should be done with caution. Dusts can be irritating to the eyes, nose and respiratory tract.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Indoor TVOC concentrations were ND (Table 1). An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were also ND.

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of

TVOC-containing products. While no measurable TVOC levels were detected in the indoor environment, VOC-containing materials were present in the building. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat. Cleaning products and flammable materials were found on countertops and beneath sinks in a number of classrooms (Picture 19). Cleaning products contain VOCs and other chemicals, which can be irritating to the eyes, nose and throat and should be stored properly and kept out of reach of students.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs in some areas (Picture 20). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off gas VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998). Consider replacing tennis balls with alternative glides (Picture 21).

Also of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to prevent excessive dust build-up. A number of fans/blades had accumulated dust (Picture 22). Fans should be cleaned periodically in order to prevent them from serving as a source of aerosolized particulates.

Conclusions/Recommendations

At the time of the CEH assessment mold and asbestos remediation of first floor classrooms appeared to have been successful based on staff observations and clearance testing by OASIS (OASIS, 2006b). However, due to continued concerns regarding roof leaks and odors in the modular classroom wing, general building conditions and the potential exposure to renovation-generated pollutants, the following recommendations are made:

General Air Quality Recommendations

1. Operate *all* ventilation systems throughout the building (e.g., gym, cafeteria, classrooms) continuously during periods of school occupancy independent of thermostat control to maximize air exchange.
2. Contact an HVAC engineering firm to examine modular AHUs and univents to improve air exchange in classrooms and the MCO.
3. Open windows to supplement the introduction of outside air and improve air exchange/comfort in classrooms. Care should be taken to ensure windows are properly closed at night and weekends during the heating season to avoid the freezing of pipes and potential flooding.
4. Utilize ceiling fans in cafeteria or station stand-up fans to circulate air from the mechanical ventilation system and openable windows.

5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters.
6. Ensure leaks are repaired and replace water-damaged ceiling tiles. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
7. Discard mold-contaminated books in MCO, conduct a thorough inspection of other materials and discard if water damaged/mold-colonized.
8. Make repairs to roof drains in modular classroom hallway.
9. Clean surface of plastic drain pipe shown in Picture 11 with an antimicrobial or mild detergent followed by soap and water.
10. Relocate lockers in the modular classroom hallway until roof drains are repaired.
11. Install elbow extensions to the terminus of downspouts around the modular classroom wing to direct water *away* from the building.
12. Place tile or rubber matting underneath water coolers in carpeted areas. Inspect carpeted area below water cooler in MCO for mold and remove if colonized.
13. For information on mold/remediation consult "Mold Remediation in Schools and Commercial Buildings" published by the US Environmental Protection Agency (US EPA, 2001). This document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.

14. Store cleaning products and chemicals properly and keep out of reach of students.
15. Clean air diffusers, exhaust/return vents and personal fan blades periodically of accumulated dust.
16. Consider discontinuing the use of tennis balls on furniture and replacing tennis balls with alternative "glides" as shown in Picture 21.
17. Develop a clear line of communication between the central maintenance department and school personnel for prompt remediation of temperature and/or ventilation concerns/complaints. This can be done by establishing a written request system (e.g., work order form) administered by a single responsible person see Appendix B as an example.
18. Consider adopting the US EPA (2000b) document, "Tools for Schools", to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.
19. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website: http://mass.gov/dph/indoor_air.

Renovations

The following recommendations should be implemented in order to reduce the migration of renovation-generated pollutants into occupied areas and the potential impact on indoor air quality:

1. Comply with MSBA regulations that require that schools receiving funds under the program for construction or renovation projects must confer with the most current edition of the "IAQ Guidelines for Occupied Buildings Under Construction" published by the

Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA) 963 CMR 2.04(2)(c),(d).

2. Ensure the faculty is aware of construction activities that may be conducted in close proximity to their classrooms. In certain cases, HVAC equipment and windows to classrooms adjacent to construction activities may need to be deactivated/closed periodically to prevent unfiltered air and vehicle exhaust from entering the building. For this reason, prior notification(s) should be made.
3. Develop a notification system for building occupants immediately adjacent to construction activities to report construction/renovation related odors and/or dusts problems to the building administrator. Have these concerns relayed to the contractor in a manner to allow for a timely remediation of the problem.
4. Consider appointing a construction liaison to coordinate efforts, facilitate communication and relay construction-related concerns between occupants, administration and construction personnel.
5. Disseminate scheduling itinerary to all affected parties; this can be done in the form of meetings, newsletters or weekly bulletins.
6. If construction barriers are used in subsequent phases of the project seal on all sides with polyethylene plastic and duct tape. Seal these barriers on the construction as well as the occupied side to provide a duel barrier. Ensure integrity of barriers by monitoring for light penetration and drafts around seams.
7. Seal around exterior doors adjacent to construction activities with weather stripping and door sweeps.

8. Inspect classrooms for cleanliness and construction barriers for integrity *daily* prior to the opening of school. Consideration should also be given to inspect construction barriers at the end of the school day prior to construction work. In addition, encourage school staff to report any breaches in construction barriers immediately to the main office during the school day.
9. Use local exhaust ventilation and isolation techniques to control for renovation pollutants. Precautions should be taken to avoid the *re-entrainment* of these materials into the building's HVAC system. The design of each system must be assessed to determine how it may be impacted by renovation activities. Specific HVAC protection requirements pertain to the return, central filtration and supply components of the ventilation system. This may entail shutting down systems (when possible) during periods of heavy construction and demolition, ensuring systems are isolated from contaminated environments, sealing ventilation openings with plastic and utilizing filters with a higher dust spot efficiency where needed (SMACNA, 1995).
10. Implement prudent housekeeping and work site practices to minimize exposure to renovation pollutants. Consider increasing the number of full-time equivalents or work hours for existing staff (e.g., before school) to accommodate increase in dirt, dust accumulation due to construction/renovation activities. To control for dusts, a high efficiency particulate air (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping/mopping of all surfaces is recommended.
11. Schedule projects that produce large amounts of dusts, odors and emissions during unoccupied periods or periods of low occupancy when possible.

12. Cover dirt/debris piles with tarps or wet down to decrease aerosolization of particulates, when possible.

13. Obtain Material Safety Data Sheets (MSDS) for all construction materials used during renovations and keep them in an area that is accessible to all individuals during periods of building operations as required by the Massachusetts Right-To-Know Act (MGL, 1983).

14. Consult MSDS' for any material applied to the affected area during renovation(s) including any sealant, carpet adhesive, tile mastic, flooring and/or roofing materials. Provide proper ventilation and allow sufficient curing time as per the manufacturer's instructions concerning these materials.

15. If possible, relocate susceptible persons and those with pre-existing medical conditions (e.g., hypersensitivity, asthma) away from areas of renovations.

16. Consider changing HVAC filters more regularly in areas impacted by renovation activities. Examine the feasibility of acquiring more efficient filters for these units.

17. Consider installing filter media to the outside of air intakes as shown in Picture 23. Although this measure will decrease the entrainment of airborne particulates, it will also limit the introduction of outside air.

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Picture 1

Original 1950's Univent, Tiles Removed from Floor

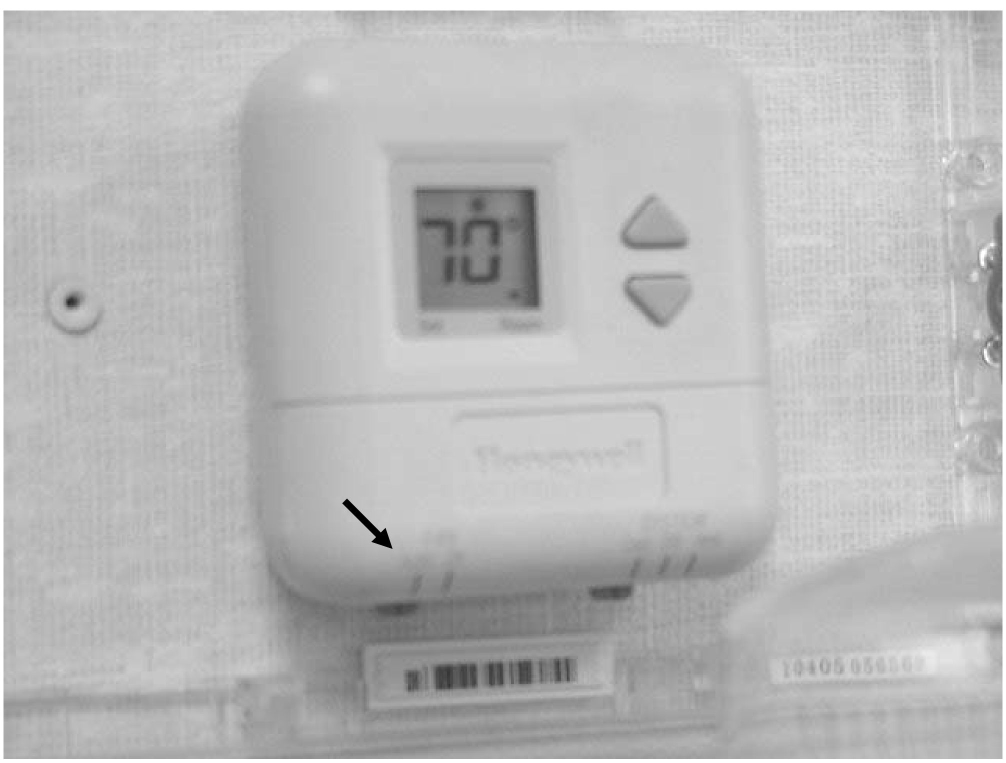
Picture 2

Damaged ACBM Floor Tiles Replaced with Standard Vinyl Floor Tiles

Picture 3

Rooftop AHUs for Modular Classrooms

Picture 4



Modular Classroom Thermostat with Fan Switch in the "Auto" Position

Picture 5

Univent Fresh Air Intakes

Picture 6

Exhaust Vent in Ceiling of Coat Closet

Picture 7

Undercut Doors of Coat Closet Arrow Indicates Airflow

Picture 8

Ceiling-Mounted Air Diffusers and Ceiling Fans in Cafeteria Classrooms

Picture 9

Leaking Roof Drain inside Modular Hallway, Note Position of Student Lockers

Picture 10

Close-Up of Leaking Roof Drain inside Modular Hallway

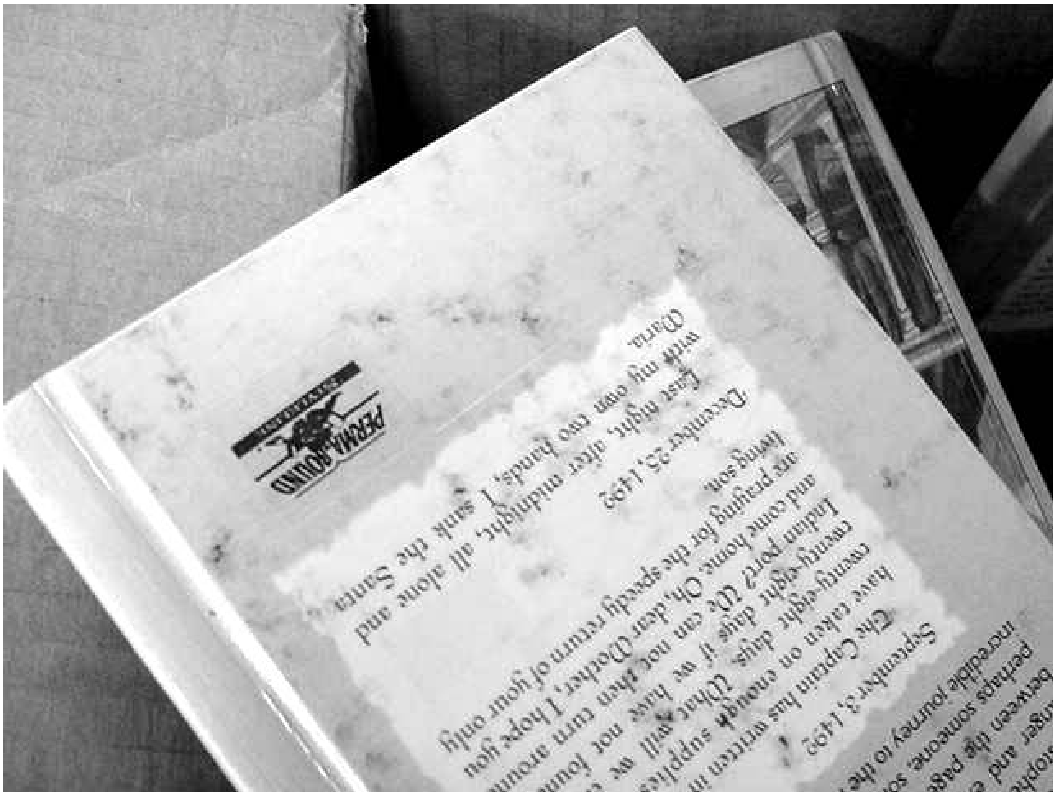
Picture 11

Close-Up of Mold Growth on Surface of PVC Drainpipe
and Standing Water on top of Student Lockers (shown in Picture 9)

Picture 12

Box of Mold-Colonized Books in Modular Office

Picture 13



Close-Up of Mold-Colonized Books (as Indicated by Dark Stains) in Modular Office

Picture 14

Water Damaged Ceiling Tile and Inactive Local Exhaust Vent in Modular Boy's Restroom

Picture 15

Water Damaged Ceiling Tile in Corner of Classroom

Picture 16

Missing Elbow Extension at the Terminus of Downspout, Modular Classroom Wing

Picture 17

Open Classroom Window, Note Construction Vehicles Operating Outside

Picture 18

Dirt Construction Vehicle Access Road behind Building

Picture 19

Cleaning Products, Paint and Flammable Materials on Countertop in Classroom

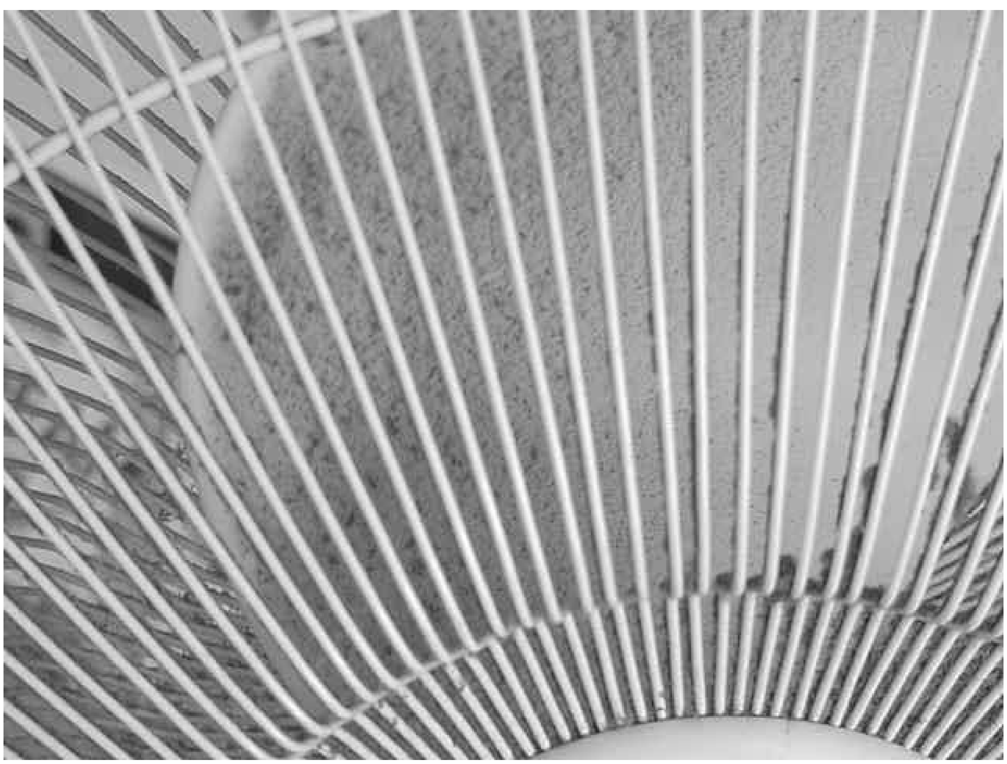
Picture 20

Tennis Ball on Chair Leg in Classroom

Picture 21

Alternative "glides" for chair legs that can be used in place of tennis balls

Picture 22



Dust Accumulation on Fan Blades in Classroom

Picture 23

Univent Air Intake Covered with Filter Media, Picture Taken at Renovation/Construction Project at Wachusett Regional High School, Holden, MA

Location: Jacobs Elementary School **Indoor Air Results**

Address: 180 Harbor View Road, Hull, MA **Table 1** **Date: 9/20/06**

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background		72	54	359	ND	ND	12				Mostly sunny, light breeze
19	20	71	51	515	ND	ND	23	Y # open: 4 # total: 4	Y univent	Y closet	Mechanical ventilation-off, DO, MT-on order
PT/OT	1	73	55	500	ND	ND	20	Y # open: 0 # total: 4	Y univent	Y closet	Mechanical ventilation-off, DO, MT-on order
17	21	72	52	569	ND	ND	24	Y	Y univent	Y closet	Mechanical ventilation-off, DO, MT-on order, flammables/cleaning products on counter, unlabeled spray bottles
18	17	74	54	589	ND	ND	19	Y # open: 3 # total: 4	Y univent	Y closet	Mechanical ventilation-off, MT-on order, DEM, PF
15	2	72	52	498	ND	ND	24	Y # open: 3 # total: 4	Y univent	Y closet	Mechanical ventilation-off

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Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
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> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Location: Jacobs Elementary School | **Indoor Air Results**

Address: 180 Harbor View Road, Hull, MA | **Date: 9/20/06**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
16	1	71	48	505	ND	ND	20	Y # open: # total: 4	Y univent	Y closet	Mechanical ventilation-off, CT-along windows, DEM
11	18	71	55	845	ND	ND	22	Y	Y univent	Y closet	Mechanical ventilation-off, DEM, DO, WD paper under sink periodic sink leaks reported, CP, 2 CT, plants
14	17	76	57	937	ND	ND	35	Y # open: 1 # total: 4	Y univent	Y closet	Mechanical ventilation-off, DO, DEM, PF, 6 WD CT
12	13	75	56	890	ND	ND	23	Y	Y univent	Y closet	Mechanical ventilation-off, difficulty opening windows reported, CP, PF
Modular #2	1	75	48	1,464	ND	ND	8	Y # open: 2 # total: 2	Y ceiling	Y ceiling	Thermostat in fan “auto” position, DO, DEM, TB, occupants gone approx 40 mins, windows open with AC on
Modular #1	22	74	63	2,720	ND	ND	23	Y # open: 2 # total: 2	Y ceiling	Y ceiling	DEM, TB, PF, windows open with AC on

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									Supply	Exhaust	
Modular #4	21	68	44	3,876	ND	ND	8	Y # open: 0 # total: 2	Y ceiling	Y ceiling	DEM, CP, thermostat in fan "auto" position
Modular #3	20	72	54	2,717	ND	ND	15	Y # open: 1 # total: 2	Y ceiling	Y ceiling	Thermostat in fan "auto" position, 4 WD CTs
Modular Office	0	80	51	642	ND	ND	11	Y # open: 0 # total: 2	Y ceiling	Y ceiling	Mechanical ventilation-off, musty odors, moldy books, water cooler on carpet
Modular boy's restroom								N	Y ceiling	Y ceiling	Strong urine/bathroom odors, local exhaust ventilation-off, water damaged CT
Modular adult restroom								N	Y ceiling	Y ceiling	local exhaust ventilation-weak water damaged CT
10	6	76	45	546	ND	ND	13	Y # open: 4 # total: 4	Y univent	Y closet	Mechanical ventilation-off
42	2	74	45	578	ND	ND	35	Y # open: 2 # total: 2	Y univent	Y wall	Mechanical ventilation-off, DO, plants

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Location: Jacobs Elementary School

Address: 180 Harbor View Road, Hull, MA

Table 1

Indoor Air Results

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									Supply	Exhaust	
Library	24	76	49	672	ND	ND	19	Y # open: 1 # total: 6	Y univent	N	Mechanical ventilation-off
Computer Lab	4	77	49	704	ND	ND	19	N	Y ceiling	Y ceiling	PF
41	10	79	51	835	ND	ND	23	Y	Y univent	Y ceiling	Mechanical ventilation-off, DO
Cafeteria Classroom A	16	78	49	856	ND	ND	21	N	Y ceiling	Y wall	Mechanical ventilation-off, DO, DEM
Cafeteria Classroom B	19	77	44	759	ND	ND	22	Y # open: 2 # total: 6	Y ceiling	Y wall	Mechanical ventilation-off, DO, DEM
Cafeteria Classroom C	17	79	49	945	ND	ND	27	N	Y ceiling	N	Mechanical ventilation-off, DO, DEM
Cafeteria Classroom D	18	79	47	740	ND	ND	16	Y # open: # total: 6	Y ceiling	N	Mechanical ventilation-off, DO, DEM, 1 CT

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									Supply	Exhaust	
Gym	22	77	44	528	ND	ND	12	Y # open: 0 # total: 4	Y wall	Y wall	
Reading Recovery Room	1	80	45	651	ND	ND	21	Y # open:2 # total: 6	Y ceiling	Y	Mechanical ventilation-off
Special Education Room	1	77	43	608	ND	ND	40	Y # open:1 # total: 2	Y univent	Y	Mechanical ventilation-off, 1 CT
24	0	77	43	571	ND	ND	23	Y # open:3 # total: 4	Y univent	Y	Mechanical ventilation-off, DEM, DO
26	1	78	44	570	ND	ND	14	Y			17 occupants gone 15 mins
28	17	78	46	703	ND	ND	20	Y # open:3 # total: 4	Y univent	Y wall	Mechanical ventilation-off, TB, CP
25	19	76	40	441	ND	ND	11	Y # open:4 # total: 4	Y univent	Y wall	Mechanical ventilation-off, DO, CP, DEM

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31	16	75	42	530	ND	ND	12	Y # open:3 # total: 4	Y univent	Y wall	Mechanical ventilation-off, DEM, TB, CP

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